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The Effects of Simulated Laser Exposure on Marksmanship Performance on the WEAPONEER Trainer

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An experiment was performed to evaluate the effects of a simulated laser exposure scenario on the accuracy of firing in a WEAPONEER marksmanship trainer. The simulated laser scenario included three conditions: no laser, a scanning laser only, and a scanning/attack laser. The simulation was achieved by adding LEDs (light emitting diodes) to the targets. Performance on the laser scenario trials was contrasted both within and between groups with performance on trials containing no laser scenario, but was matched for target exposure duration. Results showed a substantial decrement in accuracy in the scanning-alone and scanning/attack conditions. The anticipated threat of laser exposure may cause soldiers to change their target engagement strategy and impair battlefield performance. The results were explained as an effect of the behavioral contingencies used and represent a potentially significant non-sensory consequence of widespread laser use.

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ABSTRACT

An experiment was performed to evaluate the effects of a simulated laser exposure scenario on the accuracy of firing in a WEAPONEER marksmanship trainer. The simulated laser scenario included three conditions: no laser, a scanning laser only, and a scanning/attack laser. The simulation was achieved by adding LEDs (light emitting diodes) to the targets. Performance on the laser scenario trials was contrasted both within and between groups with performance on trials containing no laser scenario, but was matched for target exposure duration. Results showed a substantial decrement in accuracy in the scanning-alone and scanning/attack conditions. The anticipated threat of laser exposure may cause soldiers to change their target engagement strategy and impair battlefield performance. The results were explained as an effect of the behavioral contingencies used and represent a potentially significant non-sensory consequence of widespread laser use.

PREFACE

The authors would like to thank Mr. Jerome Molchany, for his assistance in performing the statistical analyses used here, and Mr. Walter Golz, for making the engineering modifications to the WEAPONEER.

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INTRODUCTION

The increasing use of low-power lasers in range finding, target designation, and training has increased the risk to soldiers of accidental ocular injury by lasers (1). As knowledge concerning the effects of these low-level sources on the human eye and visual abilities is disseminated to the military community, psychological effects associated with laser eye injury may appear (2). Every target may be perceived as a potentially harmful laser source. Strategies for acquiring and engaging such targets may change unconsciously, with unknown consequences on performance. The purpose of this study was to create a scenario in which soldiers attempted to engage silhouette targets that might or might not be equipped with simulated lasers. We then quantified the performance effect of anticipatory responses that developed as soldiers gained experience with this laser scenario.

In constructing the behavioral contingencies in the experiment, we attempted to model a situation in which a soldier is faced with the possibility of being exposed to a scanning laser alone, a scanning laser followed by a dangerous laser, or no laser at all. Our hypothesis was that performance on trials with simulated dangerous laser exposure would be worse than when no simulated laser exposure was present. Deterioration in performance on trials with the scanning laser alone might also be expected. This might occur if an expectancy created by the dangerous laser exposure trials led to a change in target engagement strategy by the subjects on other trials and would represent a psychological or cognitive effect on performance caused by the behavioral contingencies in our simulated laser scenario.

The implications of a psychological effect of anticipated laser exposure for training development are significant. If such effects do occur, then training programs to ameliorate the performance decrements associated with them should be considered. Such programs might include the development of special strategies of target engagement to minimize the disruption caused by lasers.

METHODS

Subjects: Subjects were 20 soldiers assigned to Letterman Army Institute of Research, ranging in age from 18 to 38. There were 16 males and 4 females in the sample. Subjects were either emmetropic or wore correction to 20/20 acuity. Subjects participated in the experiment voluntarily and were offered the incentive of a three-day pass if their marksmanship performance was in the top 50% of the subjects tested.

Apparatus: The apparatus used in the experiment was a WEAPONEER marksmanship trainer, suitably modified. The WEAPONEER has been described elsewhere (3). It consists of an M-16A1 rifle that has been adapted to fire as part of an arcade-like training device. The infrared sighting system provides precise scoring of shots, and the device is equipped to realistically simulate the recoil and noise associated with live fire.

The apparatus was modified for the purpose of this experiment to simulate a scenario in which enemy soldiers might possess man-portable anti-personnel laser weapons. This was accomplished by mounting a green and a red LED (light emitting diode) on each of the three target silhouettes used: a scaled 100-m E-type silhouette, a scaled 250-m high-contrast E-type target, and a scaled 250-m low-contrast target. A timing circuit to control the illumination of these LEDs was added to the WEAPONEER, but target presentations and data recording were accomplished using the standard WEAPONEER controls. Figure 1 shows the WEAPONEER device.

Figure 1. Line-drawing of the WEAPONEER Device.

Procedure: Subjects participated in two experimental sessions. During the first session, all 20 subjects fired the same baseline course of fire. After being permitted to zero the rifle on the 25-m zero target, subjects fired two 32-shot sequences of random target presentations. The 100-m high-contrast, 250-m high-contrast, and 250-m low-contrast targets were randomly mixed in approximately equal numbers. Target presentation times were 4 seconds (s) for the two 250-m targets and 2 s for the 100-m target.

After completion of the baseline firing, subjects were scheduled for an additional experimental session

that was generally 3-4 days later. The subjects' scores on the baseline firing were used to divide them into two groups of ten, the experimental and the control groups. This was accomplished by rank-ordering all twenty scores and then alternately assigning successive individuals to the two groups. The mean baseline performance of the two groups so formed was nearly equal; however, a few reassignments were made to make the means and standard deviations of the marksmanship scores of the two groups as similar as possible.

The experimental and control groups were treated differently during the second session. Subjects assigned to the control group completed 2 more 32-shot courses of fire. One of the series was identical to the baseline series, consisting of 4-s presentations of the 250-m targets and 2-s presentations of the 100-m target. The other series of 32 target presentations consisted of 2-s exposures of the 250-m targets and 1-s exposures of the 100-m target. Five of the subjects in the control group fired the 4-s/2-s series first, and five fired the 2-s/1-s series first. During control group trials, the LEDs mounted on the targets were never activated.

The experimental group fired two 32-shot courses of fire, both consisting entirely of 4-s/2-s presentations. However, three different trial types were mixed in approximately equal ratios throughout these 64 exposures. Type-1 trials were identical to the trials used during the baseline session; the LEDs mounted on the target were not activated during the trials.

Type-2 trials were used to simulate an enemy soldier projecting a "scanning laser" at the firer. Subjects were instructed that when a green LED located on the left shoulder of the target was illuminated, the enemy was using a laser to look for them, but had not yet found them. Subjects were told that they could continue to aim and fire at the target while the green LED was illuminated.

Type-3 trials were used to simulate an enemy soldier first scanning and then attacking with a laser weapon. Subjects were instructed that the illumination of the green LED meant that the enemy was searching for them with a scanning laser, while illumination of a red LED, located on the right shoulder of each target, meant that they had been found and were being exposed to a blinding

laser. Subjects were reminded that the laser exposure was only "pretend" and that they were in no danger. During the time the red LED was illuminated, subjects were told they could not look at or engage the target; firing at the target during this period would result in points being deducted from their score.

The timing of the LED illumination was carefully arranged to facilitate comparisons and analysis of the data. On baseline trials (Type 1) the 100-m target was exposed for 2 s; on Type-2 trials, the green LED was illuminated at 1 s and turned off at 1.5 s into the exposure. On Type-3 trials, the green LED was turned on at 1 s and off at 1.5 s; the red LED was turned on at 1.5 s and remained on until the target dropped.

For the 250-m targets, Type-1 trials consisted of a 4-s target presentation. On Type-2 trials, the green LED was turned on at 2 s and off at 3 s into the exposure. On Type-3 trials, the green LED was turned on at 2 s, off at 3 s, and was followed by the red LED being turned on at 3 s and remaining on until the target dropped. The temporal relationships of LED illumination to target exposure are summarized for each trial type in Figure 2. The experimental design is summarized in Table 1.

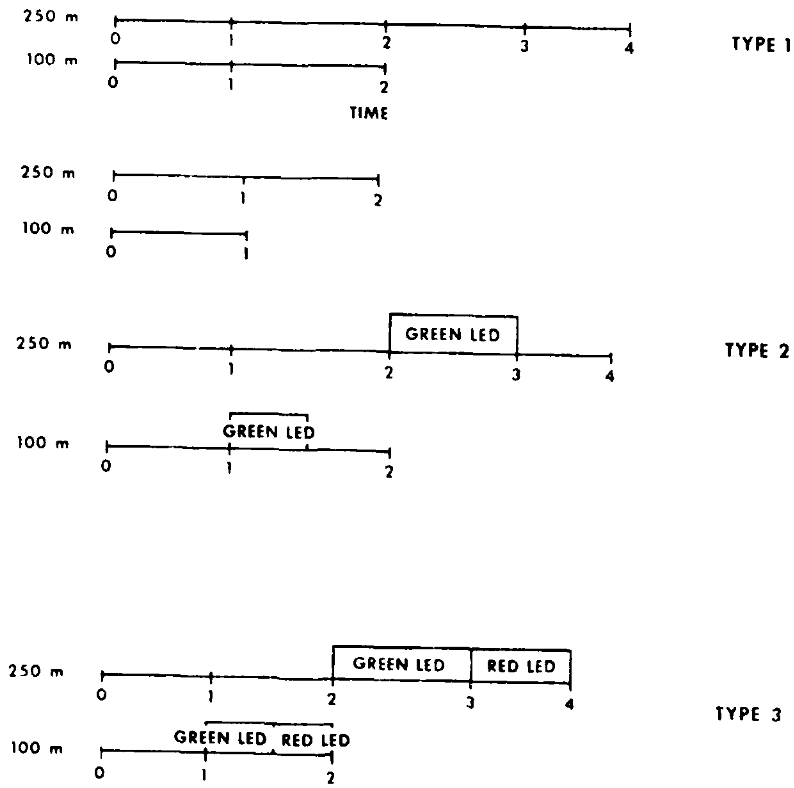

Figure 2. Graphic Representation of Timing of LEDs Used to Simulate Laser Exposure.

TABLE 1

Summary of Experimental Design

Control		Experimentals	
Session 1		Session 1	
4 s/2 s	64 trials	4 s/2 s	64 trials
Session 2		Session 2	
4 s/2 s	32 trials	Type 1	approx 21 trials
2 s/1 s	32 trials	Type 2	approx 21 trials
		Type 3*	approx 21 trials

*Type-1 and -2 trials are comparable to 4-s/2-s trials in terms of total target availability time; Type-3 trials restricted the time available to the subject to approximately the same as 2-s/1-s trials.

After completion of each 32-shot series, subjects were given feedback on their performance and allowed a few minutes' rest. At the conclusion of the experiment subjects were thanked for their participation and told that they would be notified of whether or not they had been awarded a pass (as a result of scoring in the top 50% of the firers) in a few days.

Results

The raw dependent measure used in this experiment was the hit, miss, or late score generated by WEAPONEER for each shot. These scores were used to compute a percent-hit score for each subject in each condition of the experiment. The data were then entered into $\underline{t}$ tests or analyses of variance (ANOVAs) as appropriate.

An analysis was performed comparing the baseline scores of the experimental and control groups. No significant differences between the two groups were found, reflecting the similarity of the overall marksmanship ability of the two groups at the outset of the experiment.

An analysis of variance (ANOVA) was carried out on the data by using group (control vs. experimental) as a between-subjects factor and effective target exposure duration and target distance as within-subjects factors. (Summary tables for the ANOVAs can be found in Appendix 1.) The effective target exposure duration factor was assessed by comparing the 4-s/2-s and 2-s/1-s trials for the control group with the Type-1 trials and Type-3 trials, respectively, for the experimental group. The Type-1 exposures offered the targets for the full 4- and 2-s periods, while the red LED (representing dangerous laser exposure) essentially made the target unavailable during a portion of the exposure on Type-3 trials. The effective target exposure duration was thus much closer to 2 s/1 s for Type-3 trials.

In all conditions of this experiment, consistent differences in accuracy among the three different targets were found. The main effect of target distance was significant ($F(2, 36) = 11.14$, $p < .0002$). Accuracy on the 100 m target was always higher than on either of the two 250 m targets, which were associated with generally similar performance. None of the interactions involving the target distance factor were significant. The target exposure duration factor also was significant in this analysis ($F(1, 18) = 21.35$, $p < .0002$). As might be expected, the shorter target exposure durations (2 s/1 s) were associated with considerably poorer performance than the longer durations used (4 s/2 s). This was true for both the control and experimental groups: the between-subjects group factor was not significant, nor were any of the interactions in the analysis. Figure 3 graphically displays these data.

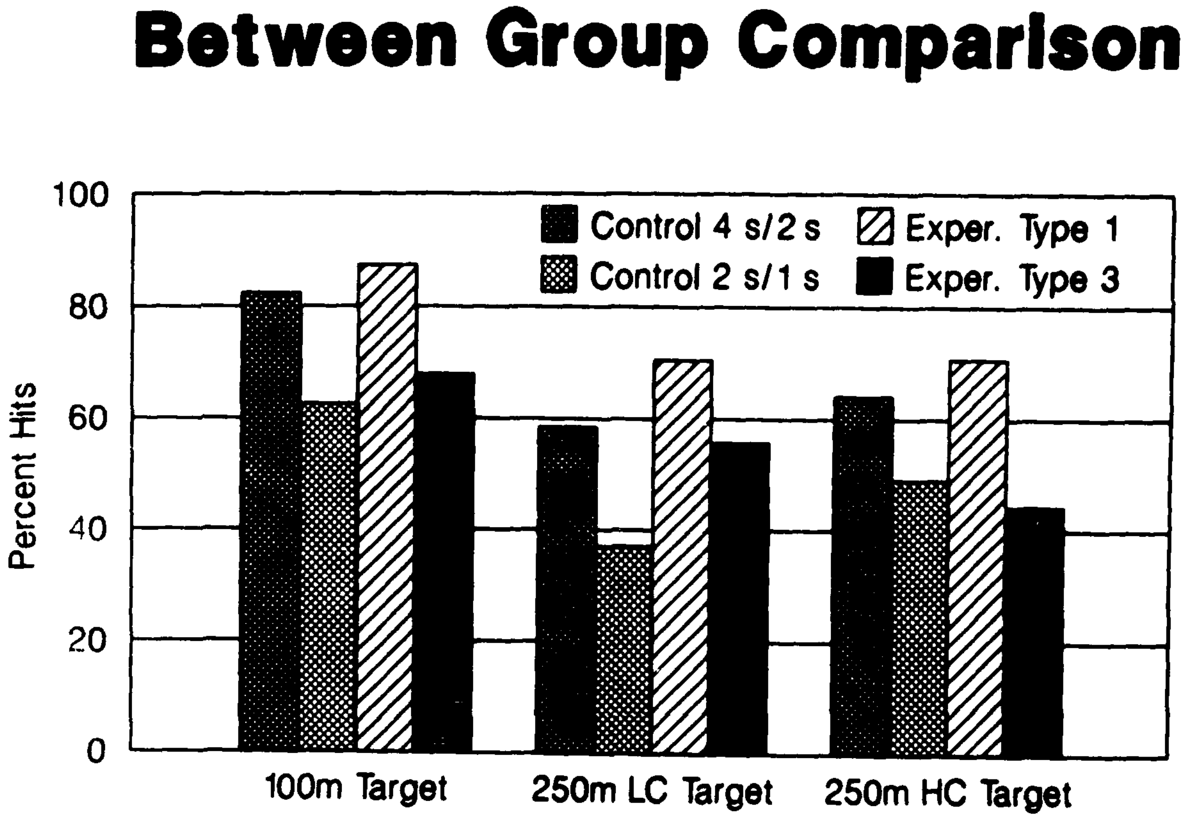

Figure 3. Histogram Showing Mean Percent Hits for Both the Control and Experimental Groups in Comparable Conditions in the Experiment for All Three Targets.

A repeated-measures ANOVA was performed on the data from the experimental group, with trial type and target distance each as three-level factors. Strong significant effects of both trial type ($F(2, 18) = 6.11$, $p < .009$) and target ($F(2, 18) = 9.42$, $p < .002$) occurred.

The effect of target was similar on the experimental group to that observed in the results of the control group. Performance was best at the shortest target distance (100 m) and was worse for both the 250-m high-contrast and 250-m low-contrast targets.

The most intriguing finding in the study was the significant effect of trial type. Performance was best on trial Type 1, declined on Type-2 trials, and was worst for Type-3 trials. Figure 4 shows the marksmanship scores for the experimental group as a function of trial type and target.

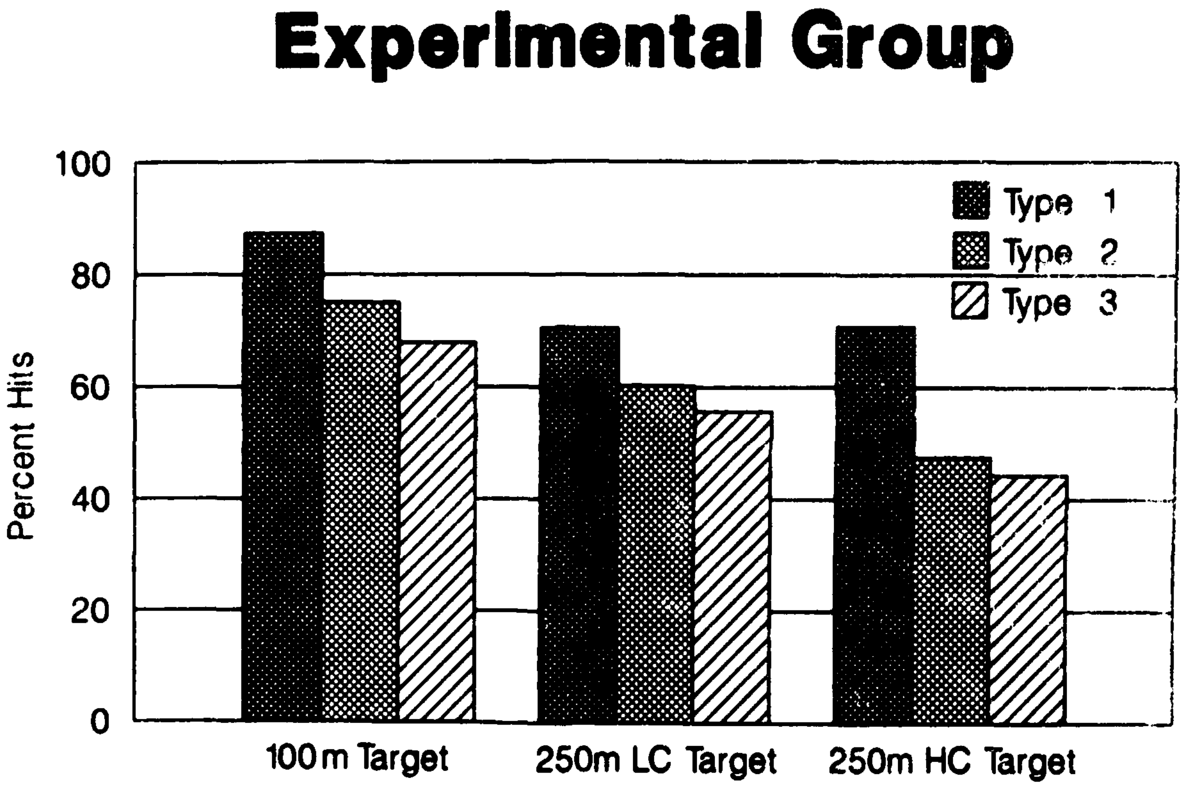

Figure 4. Histogram Showing the Decrement in Performance Observed on the three Laser-Scenario Trial Types for Each of the Three Targets.

DISCUSSION

The finding that target engagement strategies can be influenced by simulated laser exposure is important because it identifies a class of effects of laser exposure that have until now received little attention (4-7). In addition to the physical, biological and perceptual effects of lasers, the psychological reality of lasers as weapons may cause soldiers to change the way they use their weapons. This study demonstrates that individual marksmanship (at least as represented by the WEAPONEER trainer) is susceptible to disruption by the laser-exposure contingency we used. Perhaps most significant is the fact that performance was affected on trials containing only the scanning laser as well as on trials containing both scanning and dangerous lasers. The expectancy created on the scanning/attack trials generalized to the scanning-alone trials.

The overall similarity in performance between the control and experimental groups, when target exposure duration is considered, shows that the magnitude of the performance decrement observed that can be attributed to the laser scenario (experimental group results) is comparable to the magnitude of the decrement observed when we simply reduce the amount of time available to the soldier to engage the target (control group results). This suggests that the non-sensory effect demonstrated in this study can be understood as a straightforward response to the behavioral contingencies we created: because the "laser" had the effect of reducing the time available to engage the target, subjects rushed their shots and missed more often.

What we do not observe is depression of experimental group performance significantly below that of the control group; such a finding might suggest a generalized "fear" or emotional response to the threat of lasers. The likelihood of demonstrating such an effect in the laboratory is of course low, as subjects know they are in no real danger. This possibility should remind us, though, that stress can sometimes lead to improved performance by increasing arousal. Whether there would be an additional "fear effect" contributing to further performance deterioration under more realistic circumstances, or whether the stress-related arousal associated with lasers might improve performance, cannot be predicted on the basis of these results.

CONCLUSION

If lasers are to become common on the battlefield of the future (and every indication is that they will), then disruption of soldier performance by their physical, biological and psychological effects must be countered. Development of equipment and materials to protect soldiers from laser exposure and to prevent degradation of performance due to the physical and biological damage mechanisms is proceeding, as is evidenced by the recent fielding of the B-LPS (Ballistic and Laser Protective System) goggles. To effectively counter the psychological disruption caused by laser exposure, such as the disruption shown in this study, the nature and extent of the performance changes induced and their duration and stability must be explored in further behavioral research where psychological effects like the ones demonstrated here are more fully integrated with standard training scenarios.

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Appendix 1

1. Summary Table for Comparison of Baseline and Control Groups.

SOURCE	DEGREES OF FREEDOM	MEAN SQUARE	F	TAIL PROB.
MEAN	1	468250.13333	271.54	0.0000
CONTROL vs. EXPERIMENTAL (GRP)	1	1555.20000	0.90	0.3549
ERROR	18	1724.40741		
EXPOSURE DURATION (DUR)	1	11368.53333	21.35	0.0002
GRP X DUR	1	16.13333	0.03	0.8637
ERROR	18	532.37037		
TARGET (TGT)	2	4738.13333	11.14	0.0002
GRP X TGT	2	548.40000	1.29	0.2878
ERROR	36	425.20185		
DUR X TGT	2	17.03333	0.06	0.9393
DUR X TGT X GRP	2	209.03333	0.77	0.4703
ERROR	36	271.32037		

2. Summary Table for Experimental Group Comparison.

SOURCE	DEGREES OF FREEDOM	MEAN SQUARE	F	TAIL PROB.
MEAN	1	372747.37778	166.30	0.0000
ERROR	9	2241.35309		
TRIAL TYPE (TYPE)	2	3323.81111	6.11	0.0094
ERROR	18	543.74938		
TARGET (TGT)	2	3927.21111	9.42	0.0016
ERROR	18	416.92716		
TYPE X TGT	4	144.54444	0.57	0.6887
ERROR	36	255.27901		